RESEARCH ARTICLE

Performance Evaluation of Gambella Town Water Treatment Plant

Birhane Shimondi Birhane[1], Teka Girmay Hishe [2], Diress Yigezu Tenagashaw[3]

[1]*Core Processer, Dimma Werda Water, Energy Resource Development Office, Gambella, Ethiopia*
[2]*Department of Hydraulic and Water Resources Engineering, Debre Tabor University, Debre Tabor, Ethiopia*
[3]*Department of Hydraulic and Water Resources Engineering, Debre Tabor University, Debre Tabor, Ethiopia*

ABSTRACT: Water treatment is any process that improves the quality of water to make it more acceptable for a specific end-use. Safe water is used the greatest challenge facing the world today. The key problems of the water treatment plant were, filtering deteriorated water to the community. This study was conducted to evaluate drinking water treatment plants in the Gambella City from January to end of July 2018 G.C because of suitability for seasonal variation of dry and rainy season. Primary data was collected from laboratory analysis and observation. Different method was used to evaluation the efficiency of treatment plants including water quality characterization and calculating removal efficiency by comparing with world health organization and EPA standards. Four representative sample sites were selected during data collection including raw water, the sedimentation basin, the filtration basin and the final stages after the chlorination. The result shows that, in dry season the value of Turbidity color, E.coli was 11mg/L>5 mg/L, 40.83>15 Mg/l Pt., 1 > 0 CFU/100ml respectively. Whereas during rainy season Turbidity, color, Aluminum, E.coli was 30mg/L, 113>15, 0.42>0.2 and 2>0 respectively after treatment. All those values were above World health organization standards and the overall efficiency of treatment plants was 58% and 48% for dry and rainy season respectively. From this result, it can be conclude that the treatment plant was not efficient to remove pollutants such as turbidity, aluminum, E.coli and color.

KEYWORDS: Efficiency, Raw water, Treated water, Treatment plant, Water quality

https://doi.org/10.29294/IJASE.6.2.2019.1305-1312

1. INTRODUCTION

Water is the most vital component among the natural resources, and is critical for the survival of all living organisms including human, food production and economic development. Today there are many cities worldwide facing an acute shortage of water and nearly 40 percent of the world's food supply is grown under irrigation and a wide variety of industrial processes depends on water. The environment, economic growth, and developments are all highly influenced by water its regional and seasonal availability, and the quality of surface and groundwater [1].

The quality of water is declining due to the rise of urbanization, population growth, industrial production, climate change and other factors. The resulting water pollution is a serious threat to the well-being of both the Earth and its population. Pollution of river bodies has become a major problem that is becoming critical because of inadequacy or non-existence of surface water quality and sanitation measures.

The degradation of water quality has led to the destruction of the ecosystem, pollution and contamination of soil and surface water resources. The global deterioration of water quality is due to many anthropogenic activities that release pollutants into the environment, which affects aquatic ecosystems. Water quality can be consider as variables such as pH, oxygen concentration, temperature and any change in these physical and chemical variables can affect aquatic communities in several ways. Since water quality is directly related to health and it is important to determine the benefit of water, it is very important and important to test the water quality before using it for domestic, agricultural or industrial purposes. The utility of the ground water source for various purposes is determined by the physicochemical and biological quality of the water [2].

The original Gambella town treatment plant implemented in 2001 G.C by EWWCE consists of conventional components, including raw water header tank, mixing chamber and flocculator, horizontal-flow clarifier, filtration units, clear water tank, clear water pumping station, backwash water tank, air blower room, chemical building, and stand-by diesel generator house. Running at full potential, the original plant had a capacity of treating 5,000 m^3/d. In 2015, MENA-Water undertook a rehabilitation work to upgrade the capacity of the water treatment plant by mechanizing some of the operations and modifying some of the

**Corresponding Author: tekagirmay@gmail.com*
Received: 05.09.2019 **Accepted:** 18.10.2019 **Published on**: 30.11.2019

processes. Among the changes made are provision of a mechanical rapid mixing/flocculation, modification to the sedimentation tank floor, provision of tube settlers to increase clarification efficiency, provision of a mechanically rotating sludge scrapper, provision of backwash nozzles and pumps, modification to depth of filter media, modification of the chemical dosing system and the provision of additional clear water pumps. The upgraded capacity of the treatment plant has increased from 5,000 m^3/d to 10,000 m^3/d.

2. MATERIAL AND METHODS

2.1 Description of the Study Area

Gambella town has a total area of about 15.6 km^2 and it is divided into five Kebele administrations. The town is located at a distance of 777 kilometers south-west of Addis Ababa, capital of Ethiopia. Geographically the town is located at about 8°14'17" North Latitude and 34°35'11" East Longitude. The town is characterized by a gently rolling topography. This has enabled expansion of the town in all directions. The Elevation increases from the center towards North, South and East directions. Measured elevation of the study area varies from about 440 a.m.sl near the Baro Bridge to about 525 a.m.sl at the top of the Jajebe hill [3].

Baro River which is the source of water supply passes through the center of the town in the Ease-West direction, divides the town in to two north and south halves of similar topographic pattern, both draining towards the river. In the same way, Jajebe River that drains the North-Eastern part of the town and flows in the South-West direction, divides the northern half further into two With an average elevation of about 475a.m.sl[3]. The climate in Gambella town can be categorized as Desert (Qola or Bereha). The mean annual temperature of the town is about 28°C, with March being the hottest and December the coldest months. Rainfall starts towards the end of May and stops towards the end of October. Gambella receives a larger volume of rainfall per year, with an annual value of about 1189mm for Gambella town [3].

Third national censuses ran in 2016 estimated the town population to be 39,022. Regarding the current size of population, varying estimates are given by different sources. The CSA projection for the year 2016 shows a population size of 70,099 [4].

2.2 Study Design

This research was chosen an experimental study design, which was to analysis the bacteriological and physical-chemical drinking water quality in order to evaluate the performance of the treatment plant at the entrance of the river flow, outflow from the sedimentation, filtration processes and after disinfection.

2.3 Sampling Methods

Performance appraisal had carried out by comparing the concentrations of pollutants at the inlet and outlet of the treatment unit. The grab samples were collected at the inlet and outlet of the treatment unit to analyze in the standard methods for the examination of water.

The samples were analyzed for various parameters like pH, Turbidity, color, free residual chlorine, Aluminum, Nitrate, Iron, Manganese, Fluoride, Temperature, E. coli and depending on the results, performance of each unit was evaluated.

2.3.1 Sampling and Sample Size

The selection of the sampling points was considering at each location individually; however, the following general criteria were normally applicable: Samples taken from the sampling points should be representative of the various sources from which the water comes or enters the system, but only one source was considered in this study [5]. Water sampling for laboratory analysis was taken twice per month with seasonal variation sample in the treatment plant, raw water and treated water, sedimentation effluent and filtration effluent. The sampling frequency was taken in accordance with ESA of the potable water specification twice per the dry and wet season [6].

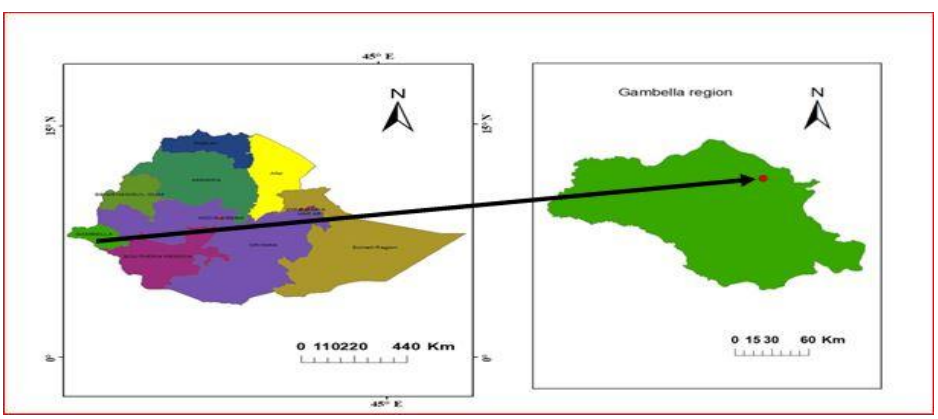

Figure 1 Study Area Location

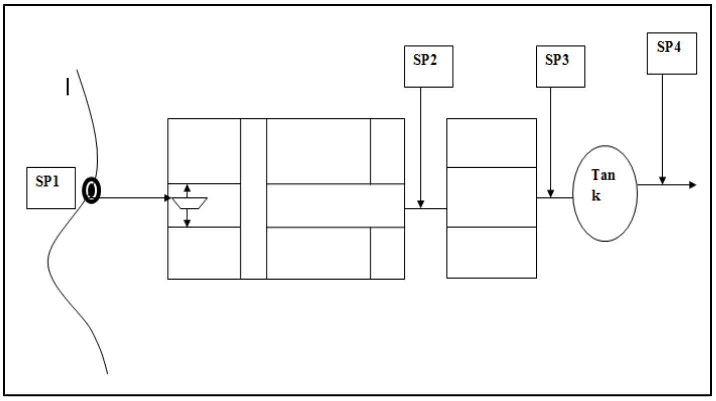

Figure 2 Location of Sample point

Where **SP1**= sampling point one from Baro river, **SP2**= sampling point two after coagulation - flocculation and sedimentation, **SP3**= sampling point three after filtration, **SP4=** sampling point four after dis infection

2.3.2 Sampling procedure

Sampling Techniques**:** Samples of treated and untreated water supplies had taken from the designated location within the water treatment plant. A water sample had taken in the morning in January and July, covering both the dry and the wet season of the month. Samples had taken twice in the appropriate month from which the mean can be calculated and recorded. All sampling would be carried out according to standard methods and procedures. The number of samples taken for each season was 24 and for two months and totally 48 samples were taken during the study period of January and July.

2.3.3 Laboratory Methods

Field and laboratory measurements were carried out according to the standard methods APHA in the laboratory within 24 hours with three replications reading per sample [7].

- **Physical Tests**
  Turbidity was measured by Turbidity meter. TDS determined by TDS Tester 11 meter and gravimetric method, color would be with the aid of photometer and temperature determined by pH meter.
- **Chemical Test**
  The concentration of hydrogen ions (pH) was determined by means of a PH meter by inserting the probe into the sample or (photometer).All chemical analyzes, residual chlorine, iron, manganese, zinc, fluoride, nitrate, and aluminum were measured using a spectrum-photo-meter: water test tubes vacuum and sample water test tubes submerged in the instrument and the measured value was recorded. The device would be cleaned with a cloth to allow the absorption of free light. The instrument was filled with a sample of water and the instrument was switched on, the reading was recorded.
- **Microbial Tests:**
  The membrane filtration process (MF) was used, after mixing the sample by inverting, 100 ml of water sample was added through the cellulose filter membrane filter (0.45 µ) several times its container. Then it was transferred to the selective isolation medium to incubate at the correct temperature and time for 24 hours according to APAH[7].
  Fecal coli forms and forms of Escherichia coli were determined by membrane filtration techniques using an incubator at 44 ° C and 37 ° C for a fair test. The complete laboratory analysis was performed according to standard methods and procedures.

2.3.4 Data Analysis

After collecting all the necessary data from the individual study parameters of laboratory and observation results were determine and compare the average. It also compared with drinking water quality standards of ESA & WHO guideline.

2.4 Overall efficiency of the plants

The overall efficiency of the plants was calculated using the Log Removal value (LRV) and overall parametric efficiency respectively[8].

$$\text{remval efficiency}(\%) = \frac{\text{conc.in} - \text{conc.out}}{\text{conc.in}} * 100 \text{ .... Eq. (1)}$$

3 RESULTS AND DISCUSSION

3.3 Water quality of raw water and treated water

The water quality supplied to the treatment plant was analyzed to evaluate the performance of Gambella Treatment Plant. For this purpose, samples were collected from the upstream side of the raw water and treated water from the plants. The results indicate that most of the water quality parameters except the Color, Aluminum, turbidity, suspended solid and E. coli microbial contents were within the limits of WHO drinking water quality guideline as shown on Table 1.

Table 1 Water quality of raw water and treated water during dry and rainy season

S.No.	Parameters	Unit	dry season		Rainy season	
			Raw water	treated water	Raw water	treated water
1	Color	mg/L	100	40.83	330	113
2	pH		7.9	7.4	7.95	7.65
3	Turbidity	NTU	19	11	140	30
4	Free chlorine	mg/L	0.02	0.23	0.05	0.27
5	total chlorine	mg/L	0.011	0.21	0.03	0.16
6	Zink	mg/L	0.225	0.07	0.59	0.25
7	Manganese	mg/L	0.202	0.08	0.25	0.17
8	Iron	mg/L	0.086	0.02	0.21	0.07
9	Fluoride	mg/L	0.33	0.27	0.47	0.4
10	Aluminum	mg/L	0.268	0.2	0.143	0.42
11	Sulphide	mg/L	0.012	0.025	0.17	0.05
12	Nitrate	mg/L	3	1.2	3.6	2.19
13	TDS	mg/L	80	90	220	230
14	E. coli/100ml	CFU	6	1	8	2
15	SS		24	7	98	87

Temperature

The water temperature was ranged from the lowest value in treated water (SP4) in the rainy season and the highest value of raw water (SP1) 33.5°C in the dry season (Table 1). The raised of temperature in dry seasons than in humid seasons could be due to long and high sunlight intensity[9]. Increase in water temperature reduces flock settlement [1,10].

Turbidity

The mean value of raw water (SP1) turbidity was found in the range of 19 to 140 in dry and rainy season respectively. The highest turbidity was observed in water source of the rainy season and the lowest dry season. The lowest treated water (SP4) turbidity value was 11 NTU in the dry season, while the highest value was 30 NTU in rainy season. The maximum and minimum turbidity values recorded in this study was exceeding the permissible limits 0-5 NTU[5].

Color

The study shows the mean value of raw water (SP1) color were found in the range of 100 to 330 mg/L Pt. in dry and rainy season respectively. Color concentration of treated water (SP4) was 40.83 and 113 mg/L Pt., in the dry and rainy seasons respectively; which is above the WHO and ESA recommended limits of 15mg/L Pt. ([5]. Comparison between both season higher values of raw and treated water in the rainy season may be due to the increase in these rains due to high runoff from the Baro River causes much agitation and mixture of debris in the water which are ended in the river water. In addition, domestic wastes were contributed to increasing the turbidity [11]. Therefore, based on the color evaluation compared with WHO standard the treated water from Gambella treatment plant was not acceptable for esthetical criteria.

Total Dissolved Solid

The lowest average value of raw water (SP1) total dissolved solids (TDS) was 80 mg/L in dry season; while the highest value treated, water (SP4) was 230 mg/L in the rainy season of Gambella treatment plant. Higher concentrations of TDS in the rainy season are attributing to precipitation, especially in densely populated cities and industrial areas where they carry pollutants in the atmosphere[12]. The TDS values recorded in this study were within the permissible limits (1000 mg/L) of ESA and WHO standards for drinking water[6] and treated water TDS value was greater than the raw water because of aluminum sulfate dosage and its salt concentration.

Fluoride

The mean value of raw water (SP1) Fluoride was found in the range of 0.33 to 0.40 treated waters (SP4) in dry and rainy season respectively. Compare the mean value of treated water (SP4) fluoride the highest concentration of fluoride was found in surface raw water (SP1) source and the lowest treated water (SP4) concentration 0.27 mg/L in the rainy and dry seasons, respectively. Whereas, both season raw and treated water, it was below the recommended ES and WHO guideline values of 1.5 mg/l [5].

Iron

The mean value of raw water (SP1) iron was found in the range of 0.086 to 0.21 mg/L in dry and rainy season respectively. Iron concentration of treated water (SP4) was 0.02 and 0.07 mg/L in the dry and rainy seasons; which is below the WHO and ESA recommended limits of 0.3 mg/L [5].

Nitrate

Nitrate (NO_3) concentration was ranged from 1.2 mg/L in treated water (SP4) dry season and the highest value 3.6 mg/L raw water (SP1) in rainy season. The concentration of raw water of dry season at (SP1) and

treated water (SP4) was 3 mg/L 2.19 mg/L respectively. The study showed that the NO_3 concentration was increased during rainy season due to the precipitation and erosion of certain salts rich deposits, which contains nitrate. The nitrate values within the allowable limits both season raw and treated water (less than 10 mg/L) [5].

Zinc

The mean value of raw water (SP1) Zinc concentration were found in the range of 0.225 to 0.59 mg/L in dry and rainy season respectively and for treated water (SP4) the value was 0.076 and 0.25 mg/L in dry and rainy season. The highest zinc was observed in water source (SP1) of the rainy season and the lowest dry season (Table3.1). Higher values of raw water (SP1) zinc in the rainy season may be due to the increase of these rains due to high runoff from the Baro River causes much agitation and mixture of debris in the water which are ended in the river water. Likely concentration of Zn in drinking water is 0.1 - 0.245 mg/L. The desirable limit of zinc established by the Ethiopian Quality Standard is 0.1 mg/L and the maximum permissible limit is 5 mg/L.

The concentration of Zn in the treated water samples of the area ranges between 0.1 to 0.25 mg/L. Save for a few samples the concentration of Zn in the surface water is more than the desirable limit but less than the maximum permissible limit.

Manganese

The desired and permissible level of manganese in drinking water is 0.05 mg/L to 0.5 mg/L respectively. The concentration of manganese in the untreated surface water (SP1) of the area ranged from 0.20 to 0.31 mg/L during dry and rainy season respectively. However, the concentration of manganese treated water 0.01 and 0.17mg/L dry and rainy season respectively, which is within the desired level and below the permissible limit. The treated surface water of the area thus does not appear to be a manganese hazard.

Aluminum

The average values of aluminum at treated water (SP4) was ranged from 0.20 mg/L and the average value of the raw water at (SP1) concentration was 0.42 mg/L and 0.26 to 0.143 mg/L at dry and rainy season. The results show high percentages of residual aluminum in drinking water in the rainy season, this result due to high aluminum dosage to remove high turbidity .Residual aluminum its values above the ES and WHO limits (0.2 mg/L). The compound aluminum sulphate ("alum") is very widely used in water treatment to remove colour and non-filterable matter in raw waters.

Epidemiological studies show exposure to Al and Mn to be risk factors associated with mental impairment. Specifically, Al is associated with the development or acceleration of onset of Alzheimer's disease [5].

Residual chlorine

The mean values treated water (SP4) of residual chlorine were ranged from 0.23 mg/L at Treatment Plant in dry season to 0.27 mg/L in rainy season and the average value of raw water (SP1) concentration of free chlorine 0.02 to 0.05 mg/L in dry and rainy season (Table 1). High temperatures is directly affect the concentration of chlorine and its evaporation, thus the largest doses of chlorine were added to the water in most of the water purification stations in rainy season because of the increase of pollution [1]. Residual chlorine its values within the ESA and WHO limits (0.2-0.5mg/L).

Suspended solid

Based on the analysis the mean value of raw water suspended solid was found in the range of 24 to 98 mg/L in dry and rainy season respectively. Suspended solid concentration of treated water was 7 and 87 mg/L in the dry and rainy seasons; which the highest value from the treated water was in rainy season because of runoff and erosion [11,13].

E. coli

The study discovered that, both E. coli in both season water sources and treated water were above the recommended limits of WHO drinking water guideline values (0 CFU/100 ml) in the rainy season. This may be due to high runoff during the rainy season and failure of the treatment plant [14].

3.4 Comparisons of water quality before and after upgrading the plant

When comparing the water quality parameter between before and after up grading three parameters exceeds the WHO water quality standard limits. These shows there was coming the water quality deteriorations after the up grading of some component of the treatment plant.

Form the Table 2 the result showed that the E. coli in upgraded treatment plant was higher than the original treatment plant because due the rearrangement of treatment plant component, the effluent water quality was deteriorating. These lead to the inefficient performance of chlorine disinfection because of high turbidity. Therefore, this inefficient performance of chlorine disinfection was suitable for passage of bacteria through the plant and re-grow.

3.5. Sedimentation (SP2) turbidity and E. coli Removal efficiency

According the study, the removal efficiency of sedimentation during rainy season was 47.6% and 68.5% during dry and season. Therefore, as shown in Table 2 and 2(a) the turbidity removal efficiency of Sedimentation processes of treatment plant was lower than that of EPA standards[15] and WHO standards. E. coli removal also 25 % and 33% for dry and rain season which was above the WHO standards. This implies, sedimentation tank is not efficient on Turbidity and bacterial removal.

3.6. Filtration turbidity and E.coli Removal efficiency

According the study, the removal efficiency of Filtration remove turbidity was 45.5 % during rainy season of the Filtration processes and 47% during dry season. Therefore, as shown in Table 2 and 2(a) above the turbidity removal efficiency of Filtration processes in the treatment plant is lower than that of EPA standards 99.9%[15] . The E. coli removal efficiency was also 33.33% and 50% for dry and rainy season.

Table: 2 Comparisons of water quality before and after the upgrading treatment plant

S.No.	Water quality Parameter	Unit	Quality		WHO standard
			Original TP (Tariku,2013)	Upgrade TP (Own Lab.)	
1	Turbidity	NTU	6	30	<5.0
2	Color	Mg/l Pt.	5.0	113	<15
3	pH	-	6.8	7.65	6.5 – 8.5
4	Free residual chlorine	mg/l	0.2	0.25	0.2 – 0.5
5	Aluminum,	mg/l	0.52	0.42	0.5
6	Nitrate	mg/l	1.62	2.19	10
7	Iron	mg/l	Nil	0.07	0.3
8	Manganese	mg/l	0.018	0.17	0.05
9	Fluoride	mg/l	0.71	0.40	1.5
10	Temperature	^0C	15	21	20-30
11	E.coli	CU	Nil	2	Nil

Table 2(a) Turbidity concentrations during dry season (mg/L)

Sample dry (2018 G.C)	Sample from Raw water (SP1)	Sedimentation tank out let(SP2)	Efficiency (%)	Filtration (SP3)	Efficiency (%)
Turbidity	135	42.5	68.5	22.5	47
E.coli	8	6	25	4	33.33

Table 3 Turbidity and E.coli concentrations during rainy season (mg/L)

Sample rainy (2018 G.C)	Sample from Raw water (SP1)	Sedimentation tank out let(SP2)	Efficiency (%)	Filtration out let (SP3)	Efficiency (%)
Turbidity	21	11	47.6	6	45.5
E.coli	6	4	33.33	2	50

Table 4 the overall treatment plant efficiency during dry season

Parameters	Concentration of Raw water quality	Concentration of Treated quality of water	Efficiency (%)	WHO	Description
Turbidity	19	11	42.1	5	Not efficient
Aluminum	0.268	0.2	25.4	0.2	Efficient
Nitrate	3	1.2	60.0	10	Efficient
Manganese	0.202	0.08	60.4	0.5	Efficient
Iron	0.086	0.02	76.7	0.3	Efficient
Fluoride	0.33	0.27	18.2	1.5	Efficient
Color	100	40.83	59.2	15	Not efficient
E.coli	6	1	83.33	0	Not efficient

Table 5 the overall treatment plant efficiency during rainy season

Parameters	Concentration of Raw water quality	Concentration of Treated quality of water	Efficiency (%)	WHO	Description
Turbidity	140	30	78.6	5	Not efficient
Aluminum	0.143	0.42	-193.7	0.2	Not efficient
Nitrate	3.6	2.19	39.2	10	Efficient
Manganese	0.25	0.17	32.0	0.5	Efficient
Iron	0.21	0.07	66.7	0.3	Efficient
Fluoride	0.47	0.4	14.9	1.5	efficient
Color	330	113	65.8	15	Not Efficient
E.coli	8	2	75	0	Not efficient

Table 6 Over all water treatment plant efficiency

S.No	Parameters	Unit	Jaunary 2018 Dry Season		Efficiency (%)	July 2018 Rainy Season		Efficiency (%)
			Raw water	Treated water		Raw water	Treated water	
1	Color	mg/l Pt.	100	40.83	59.2	330	113	65.8
2	pH		7.9	7.68	2.8	7.95	7.65	3.8
3	Turbid	NTU	19	11	42.1	140	30	78.6
4	Mn	mg /l	0.2	0.08	60.0	0.25	0.17	32.0
5	Zi	mg /l	0.225	0.076	66.2	0.59	0.25	57.6
6	Fe	mg /l	0.086	0.02	76.7	0.21	0.07	66.7
7	NO3	mg /l	3	1.2	60.0	3.6	2.19	39.2
8	E.coli	CFU /100ml	6	1	83.3	8	2	75.0
9	SS	mg/l	24	7	70.8	98	87	11.2
average					57.9	average		47.8

4 CONCLUSIONS

The performance of Gambella water treatment plant for a short-term observation around seven months January to the end of July 2018, the resulting conclusions were as follows.

The removal efficiency of Gambella treatment plant has a low rate of elimination of turbidity and suspended particles by flocculation, sedimentation and filtration processes. The performance sedimentation basin has not efficient operation of turbidity from the intake and the increase in demand on water supply leads to reduce the detention time in the basin and hence high turbidity in the outlet water turbidity.

Gambella Treatment Plant was not efficient in bacterial removal where chlorination applied was not efficient because of high turbidity of filtered water and these were suitable for hiding of bacteria. The residual chlorine from the effluent water in the treatment plant was low and not met the residual chlorine standard at each point of user community. Generally, four parameters values (Turbidity, Color, Aluminum, *E. coli*) were exceeded the permissible limits. The drinking water produced from the Gambella treatment plant has contained than the original treatment plant in which the stages of water treatment were characterized by the old condition compared to the first before up grading TP.

The result in this study indicates that, some of the physicochemical parameters analyzed values do not conform to either the Ethiopian Compulsory Standard guideline values. The water sources that do not conform to National Standard will result to the public health problem in long time exposure. The overall and unite process efficiency of treatment plant in the study area were not satisfactory performance.

The study concluded that the treatment plants were still technologically appropriate to deliver safe water to the public, but giving attention on an arrangement of

treatment plant component and technical skills on water quality monitoring may improve the observed negative findings on physical, chemical and bacteriological quality.

REFERENCES

[1]. Hassan, F.M. and A.R. Mahmood, 2018, Evaluate the efficiency of drinking water treatment plants in Baghdad City—Iraq. J. Appl. Environ. Microbiol, **6,** 1-9.

[2]. Al-Mashagbah, A.F., 2015, Assessment of surface water quality of king abdullah canal, using physico-chemical characteristics and water quality index, Jordan. Journal of Water Resource and Protection, 7(04), 339.

[3]. Megersa, E., A. Mengistu, and G. Asebe, 2017, Nutritional Characterization of Selected Fodder Species in Abol and Lare Districts of Gambella Region, Ethiopia. J Nutr Food Sci, **7**(581), 2.

[4]. CSA, 2015, The Federal Democratic Republic of Ethiopia Central Statistical Agency Gambella Region Statistical Report. 16.

[5]. WHO, 2013, The world health report, changing the history, comprehensive prevention, treatment and care report.

[6]. ESA, 2013, drinking_water_specifications.

[7]. Association, A.P.H., et al., 1915, Standard methods for the examination of water and wastewater. 2, American Public Health Association.

[8]. Sisay, T., A. Beyene, and E. Alemayehu, 2017, Journal of Environmental Science and Pollution Research. J. Environ. Sci, 3(3), 208-212.

[9]. Hart, A. and N. Zabbey, 2005, Physico-chemistry and benthic fauna of Woji Creek in the Lower Niger Delta, Nigeria. Environment and Ecology, 23(2), 361-368.

[10]. Mohammed, A.A., S.A. Shaker, and A.A. Shakir, 2012, Sustainability and performance evaluation of drinking water treatment plants: a case study in Iraq of Al-Krama project. Australian Journal of Basic and Applied Sciences, 6(9), 510-516.

[11]. Al-Obaidi, A.H., 2009, Evaluation of Tigris river quality in Baghdad for the period between (November 2005-October2006). Engineering and Technology Journal, 27(9), 1736-1745.

[12]. Mahinge, A.S. and I.P. Khedikar, Performance Evaluation of Water Treatment Plant at MIDC Hingna, Nagpur-A Review.

[13]. Gangwar, R., et al., 2012, Assessment of physico-chemical properties of water: River Ramganga at Bareilly, UP. Journal of Chemical and Pharmaceutical Research, 4(9), 4231-4234.

[14]. Elisante, E. and A.N. Muzuka, 2016, Sources and seasonal variation of coliform bacteria abundance in groundwater around the slopes of Mount Meru, Arusha, Tanzania. Environmental monitoring and assessment, 188(7), 395.

[15]. Hess, A.F., A. Rachwa, and M.J. Chipps, 2002, Filter maintenance and operations guidance manual. American Water Works Association.